Internationalizing the political economy of hydroelectricity: security, development, and sustainability in hydropower states

Article (Accepted Version)

Internationalizing the political economy of hydroelectricity: Security, development, and sustainability in hydropower states

1. Introduction

Immediate and drastic greenhouse gas emission reductions are needed to reduce climate change. As the International Renewable Energy Agency and International Energy Agency (2017) argue, meeting the goals enshrined in the Paris Agreement—limiting global temperature rise to below 2 degrees Celsius—demands we reduce the carbon dioxide intensity of the global economy by 85% in 35 years. Reaching such targets will necessitate low-carbon transitions across multiple sociotechnical domains, especially electricity. For as Brown and Sovacool (2011) note, electricity is the single largest source of aggregate greenhouse gas emissions in most countries; projections suggest it will be the fastest growing energy sector in the future; it reaches more people than other energy systems (about 4.3 billion people have reliable access to it compared to only 2.1 billion people accessing motorized transport); and, given that efforts are underway to electrify the transport sector, the global use of electricity will only intensify. Geels et al. (2017) also emphasize that the world must accelerate sociotechnical systems of energy and electricity towards 'deep decarbonisation.' Sustainable energy is therefore becoming a policy priority for many countries and global governance bodies, and at the heart lies choices over which low-carbon forms of electricity supply to support (Newell 2018).

Clearly, one big decision for many countries (and investors and institutions) is whether to encourage large hydroelectric dams. Hydropower remains, by a wide margin, the largest source of renewable electricity around the world, both in terms of installed capacity and global investment flows. According to the International Energy Agency (2016), hydropower provided about 16.3 percent of the world's electricity and about 85 percent of its *renewable* power in 2015. Hydroelectric dams generated at least some grid-connected hydroelectricity in more than 150 countries: at least 50 percent of total electricity in more than 60 countries and greater than 90 percent in more than 20 countries (Hancock and Sovacool 2018). Haas (2008: 86) argues that dams are the types of infrastructure that 'most fundamentally affect human settlement patterns, livelihoods, health, and the environment,' given that they impound about 14 percent of all global water runoff and operate on 60 percent of the world's 227 largest rivers.

Advocates of hydropower frequently credit it with having advantages over other forms of electricity, including very exceptional durability and reliability throughout their long periods of operation, higher efficiencies, small costs for operation and maintenance, and vast 'storage' of energy in reservoirs (International Hydroelectric Association 2003; Kammen 2004; Cernea 2004). Hydropower has considerable potential for places like the developing parts of Africa, Asia, and South America, where demand for energy is expected to grow significantly (International Energy Agency 2014; Schneider 2013). In addition, hydroelectric dams can do more than generate electricity; they can regulate water flows, provide fresh water, mitigate the effects of floods, and irrigate crops (Lejeune and Hui 2012). The Intergovernmental Panel on Climate Change (IPCC) praised hydropower as a 'proven, mature, predictable and typically price-competitive technology' and noted that 'hydropower has acted as a catalyst for economic and social development by providing both energy and water management services, and it can continue to do so in the future' (Kumar et al. 2011: 441). Even though the International Energy Agency (2012: 7) laments that 'hydropower is too often overlooked in energy policies', it projected that 'annual hydropower capacities and generation should by 2050 roughly double from current levels.'

However, a body of research has come to oppose large hydroelectric dams for a combination of political, economic, environmental, and social reasons (World Commission on Dams 2000). Scudder (quoted in Leslie 2014: 5) writes that 'large dams not only aren't worth their cost, [but] many currently under construction will have disastrous environmental and socio-economic consequences.' McCully (2001) opines that the corporate, financial, and development partners behind hydropower alliances form an 'iron triangle' that continually transfers revenues from developing countries to developed ones. Eissa (2008) and Zeitoun and Warner (2006) warn of 'hydro-hegemony' and unjust domination occurring as international conglomerates seek to impose their development and energy agendas on poor and fragile nations, or when a dominant nation uses hydropower to exert its influence over neighboring states. Hancock and Sovacool (2018) mention the possibility that hydropower countries are prone to a 'resource curse.' At their worst, major hydropower projects can become a 'hydrological weapon of mass destruction' (Wolf 2007: 243), with pollution and heavy withdrawals of water causing disease, the collapse of ecosystems, and societal strife (Lundquvist 1998).

Which is it: benefit or curse? In this study, we examine how major hydropower states—those that generate at least 70% of their national electricity from all types or classes of hydropower dams—perform from 1985 to 2014 on selected indicators cutting across national security, poverty, economic development, debt, corruption, and the environment. We compare the performance of major hydropower states with two other mutually exclusive reference classes of countries: members of OPEC and all other countries. This is precisely so our analysis moves away from "dam-centric" or single case study approaches to more comprehensive analysis at the national scale. In doing so, we analyze the effect of countries' hydropower supply rates (generation of electricity) on security, political governance, economic development, and climate change.

In proceeding to examine the political economy of hydropower in this manner, we aim to make three contributions. First, for an IPE audience, our exploration of the often-contested role of hydropower helps give meaning to broader debates over equity and sustainable development, governance, resource extraction, security, technology, centralization, climate change and the environment, policy and scale—political and policy discussions surrounding the provision of reliable, affordable, safe, and environmentally benign energy services. At one level, these discussion revolve around the complex drivers behind energy investments in rising geopolitical powers such as Brazil, China, India and South Africa (Schmitz 2017; Baker et al. 2017; Power et al. 2016) as well as changing regimes of energy finance (Di Muzio and Ovadia 2016). At another level, the debate is symbolic of future global struggles to simultaneously expand access to energy services while minimizing environmental degradation and ensuring sustainable development (Rafey and Sovacool 2011; Kuzemko et al. 2016; Newell 2018). Bakker (1999), for one, calls hydropower one of the most visible aspects of a global shift in the geopolitics of resource exploitation. However, our results also bring into focus some of the pernicious tradeoffs that can occur as one seeks to transition to large-scale sources of energy supply: bringing in jobs and generating economic activity, but also inviting corruption; seeking to supplant fossil-fuels (and lower carbon emissions), but only by increasing levels of debt, or creating new energy security threats. Finally, our analysis bears resemblance to the 'resource curse' debate ongoing in IPE (and other fields) (Auty 1993; Karl 1997; Humphreys et al. 2007), and our research design intentionally compares major hydropower states with others (such as those belonging to OPEC) to better understand whether hydroelectric countries are similarly 'cursed.' Despite these links, Hancock and Sovacool (2018) argue that so far hydropower remains understudied in IPE scholarship. Keating (2018: 199) also writes that hydropower "necessitates an IPE analysis" because it involves multiple political actors with competing norms operating across multiple scalar levels.

Second, for the energy studies, development studies, and hydropower studies communities, we seek to move beyond research dominated by single country/project case studies (e.g. Three Gorges Dam, or Nepal), utilizing single methods (e.g., performing an Environmental Impact Assessment or modeling future capacity), or assessing only a single dimension to hydropower (e.g. its financial risk, or jobs created). Mixed methods and comparative research is incredibly rare within the academic communities exploring these topics (Sovacool and Walter 2018). Instead, our approach is comparative (involving multiple classes of countries), mixed-methods (two different statistical analyses separately conducted in three timeframes), and multidimensional (covering economic, political, and even military and environmental aspects).

Third, we seek to inform practice and implementation of policy. Today's investments in technologies like hydroelectric dams will lock in energy trajectories for decades to come. Plans to build large dams continue, on the grounds of promoting security of supply and electrification— especially for the benefit of the 1.3 billion people residing in rural areas of the world (mostly in Africa and Asia) who do not have access to modern energy services (International Energy Agency 2014). Of the $11.1 trillion the world was anticipated to spend on energy infrastructure from 2005 to 2030, $1.9 trillion was expected to go exclusively to hydropower (Haas 2008). For these reasons, the hydropower industry sits at a critical juncture where much of its global capacity has yet to be built (Sternberg 2010: 713). Properly understanding the broader impacts of the technology, and of the assumptions underpinning the industry's expansion, is essential to properly weighing its costs, benefits, and future role.

2. Literature Review: Generating Hydropower Hypotheses

We began our study with an extensive review of the academic literature, generating from separate sets a list of six hydropower hypotheses (see Table 1) for our empirical analysis. We hypothesize that major hydropower states would exhibit comparatively more conflict, experience more poverty and corruption, have lower economic growth rates, greater rates of public debt, and emit more emissions of CO_2 than non-major hydropower states. The (sometimes vast) academic literature supporting each of these hypotheses is explored in detail in this section of the paper.

Table 1: Hydropower Dimensions, Hypotheses, and Affiliated Disciplines

Dimension	**Hypothesis**	**Disciplines**
Security	Hydropower increases conflict.	Security studies, geopolitics, water resources management, transboundary governance, political geography
Poverty	Hydropower increases poverty.	Social development, human security, development studies, poverty studies
Development	Hydropower decreases economic growth rates.	Development economics, energy studies, health studies, environmental science
Fiscal responsibility	Hydropower increases rates of public debt.	Project management, public policy and administration, transaction cost economics
Corruption	Hydropower increases corruption.	Governance, public policy, political science
Environmental degradation	Hydropower increases greenhouse gas emissions.	Environmental science, project management, energy studies, climate policy, physical geography

Source: Compiled by the authors

2.1 Hydropower and conflict

This hypothesis suggests that, similar to "petrostates" rich in resources such as oil (Colgan 2010; Colgan 2014), hydropower states will have more internal and external conflict, stemming largely from the water wars and water management literature (see Gleick 1993; Swain 2001 and Wolf 2007 for insightful overviews) as well as literature arguing that energy is becoming increasingly linked with other areas, notably water (Kuzemko et al 2018). In 1995, for example, World Bank vice president Ismail Serageldin suggested that 'the wars of the next century will be about water' (quoted in Wolf et al. 2005: 81). Hydropower, the thinking goes, is one critical factor that can contribute to this conflict. As Hensel et al. (2006: 391) write, '(t)he presence of hydroelectric projects on the river will increase the value of the water supply to one or both sides. Previous research has demonstrated a strong relationship between issue salience and the occurrence of militarized conflict over territorial issues, as well as decreased effectiveness of peaceful conflict management efforts.'

This literature suggests at least five possible ways that hydropower may be a catalyst for internal or external conflict (Gleick et al. 2014; Wolf 2007; White 2002). First, hydroelectric dams may serve as a military tool (for example, when state actors use them to interrupt or suspend water supplies during an international dispute). Second, they may be targeted by state actors during military campaigns. Third, non-state terrorists may attack dams to promote their agendas. Fourth, dams may be used to achieve a political goal, such as poverty reduction or provision of jobs. Fifth, water resources or dams may become a source of contention in disputes about economic and social development. Any or all may make hydropower projects sites contestation and conflict, giving rise to what Wolff (2007) calls 'hydropolitical vulnerability.' As Wolf (2007: 244) explains:

> There is no such thing as managing water for a single purpose—all water management is multi-objective and is therefore, by definition, based on conflicting interests. Within a nation, these interests include domestic use, agriculture, hydropower generation, recreation, and environment—any two of which are regularly at odds—and the chances of finding mutually acceptable solutions drop precipitously as more actors are involved.

Though this hypothesis may strike some as far-fetched, there is anecdotal evidence behind it, summarized by Table 2.

Table 2: Historical Examples of Hydropower and Intra-/International Conflict

Year	Type	Country	Description
1970	Political tool	South Africa	Troops move into Angola to occupy and defend the Ruacana hydropower complex, including the Gove Dam on the Kunene River. The goal is to take possession of and defend the water resources in southwestern Africa and Namibia.
1981	Military target	Iran	Iranian government leaders claim to have bombed a hydroelectric facility in Kurdistan during the Iran–Iraq War, blacking out large portions of Iraq.
1982	Development dispute	Guatemala	In Río Negro, 177 civilians are killed over opposition to the Chixoy hydroelectric dam.
1992	Military target	Moldova	Hostilities between Moldova and Russia in a short but intense conflict include a rocket-artillery attack on the hydroelectric turbines at the Dubossary power station on the Nistru (or Dniester) River.
1993	Military target	Yugoslavia	Serbian/Yugoslav army forces detonate explosives at the Peruća Dam on the Cetina River in an attempt to wipe out Croatian villages and the port city of Omiš. A successful Croatian counterattack allows military engineers to reach the dam and release water in time to prevent it from bursting, saving an estimated twenty to thirty thousand civilians.
1998	Military target	Sri Lanka	A civil war and related military campaigns leave infrastructure in the North, including hydroelectric dams, demolished
2000	Terrorism	Philippines	Hydroelectric dams in Mindanao become 'a source of popular local resistance because they impinge on ancestral lands and are potential targets of sabotage' by rebel groups seeking independence.
2001	Military target	Afghanistan	U.S. military forces bomb the hydroelectric facility at Kajaki Dam in Helmand Province, cutting off electricity for the city of Kandahar.
2002	Military target/terrorism	Nepal	The Khumbuwan Liberation Front (KLF) blows up a 250-kilowatt hydroelectric powerhouse in Nepals Bhojpur District, cutting off power to Bhojpur and surrounding areas. Later that year Maoist rebels destroy seven micro-hydro projects, a water supply intake, and supply pipelines to Khalanga, in western Nepal
2002	Development dispute	Botswana and Namibia	Botswana's claims for water to sustain the Okavango Delta and its lucrative ecotourism industry have contributed to a political dispute with upstream Namibia, which wants to use the water passing through the Caprivi Strip on its way to the delta for irrigation.
2005	Terrorism	Ukraine.	The Kiev Hydropower Station on the Dnieper River receives a threat that forty rail cars filled with explosives have been placed on a portion of levees holding back the reservoir.
2012	Political tool	Tajikistan and Uzbekistan	Uzbekistan cuts natural gas deliveries to Tajikistan in retaliation over a Tajik hydroelectric dam that Uzbeks say will disrupt water supplies.
2012	Military tool	Syria	After days of heavy clashes, Syrian rebels fighting the government of President Bashar al-Assad overrun governmental forces and capture the Tishrin hydroelectric dam on the Euphrates River.
2014	Military target/terrorism	Iraq	Members of the Islamic State of Iraq and the Levant (ISIL) undertake a four-day coordinated attack against the Mosul Dam, where they were resisted

			successfully by Iraqi military forces with assistance from Kurdish fighters and United States airstrikes

Source: Authors' compilation from Gleick and Heberger 2014; Sovacool 2013; Wolf 2007; Schiavo-Campo and Judd 2005; and Turton et al. 2003.

2.2 Hydropower and poverty

The hypothesis that hydropower projects can contribute to poverty is supported by a variety of disciplines advancing a broad, but interconnected, set of arguments. Granted, most of this research does not discuss increases or decreases in poverty at a state level, but are more confined, local/provincial levels or (most commonly) the scale of an individual dam. Still, we hypothesize that if such findings hold true at smaller scales, in aggregate the effect of hydropower on national level poverty could be significant.

For instance, studies have suggested that in rural areas hydropower projects may exacerbate poverty by interfering with food security, especially the vitality of fisheries or availability of agricultural land (Sarkkula et al. 2009; Pearse-Smith 2012; Wolf et al. 2005; Tilt et al. 2009). In many developing countries, hydroelectric dams can interfere with inland transport. Lack of railroads, limited road networks, and great distances between villages make rivers key to a community's livelihood (Ping et al. 2008). Another supporting argument is that hydropower projects can contribute to capture of resources by the elite, exacerbating concentration of wealth and/or marginalizing of ethnic minorities and indigenous groups (Rothfelder 2003; Smith 2003). As Wolf et al. (2005: 83) write:

> Because dams are generally situated near the ancient homes of indigenous nations, it is ultimately rural and ethnic minorities far from the central corridors of power who are typically forced to pay the price. Ill-considered development plans … generate conditions and conflicts that threaten the security of individual and group rights to culture, self-determination, livelihood, and life itself.

In Mali, for instance, dams built on the Bafing River increased land values along the river corridors where high-intensity agriculture would become possible, prompting the elite in Mauritania to rewrite land ownership regulations, ‘effectively abrogating the rights of black Africans to continue farming, herding, and fishing along the Mauritanian riverbank’ (Homer-Dixon 1994: 35). In China, hydroelectric dams in Yunnan Province were promoted as mechanisms of poverty alleviation and local employment but, in practice, have benefitted primarily urban centers and industrial clusters hundreds of kilometers away (Magee 2006). In Myanmar and Thailand, hydroelectricity has enabled government elites to capture public resources for their own profit (Matthews 2012; Simpson 2007; Greacen and Greacen 2004).

A similar strand of this argument is that resettlement and forced relocation enabling hydropower projects often cause excessive, irreversible damage. The World Commission on Dams (2000) estimated that about four million people are displaced annually by activities relating to hydroelectricity construction or operation, and forty to eighty million have been displaced in the past fifty years. As Imhof and Lanza (2010: 2) surmise, ‘big dams can contribute to development, but that progress often comes at staggering cost, in displaced and impoverished refugees, ecologically fragmented and damaged rivers, and downstream victims of destroyed fisheries and impounded sediments.’ Terminski (2013: 16) even went so far as to conclude that ‘dam building is the greatest cause of development-induced displacement worldwide.’ According to one study of World Bank–financed hydroelectric projects, 26.6 percent required involuntary resettlement of communities (Rew et al. 2000: 91).

Resettlement often poses severe hardship for communities. In the past, for example, governments in Lesotho, India, and Sri Lanka reneged on agreed-upon resettlement policies, refused to provide replacement land, or ignored treaty obligations (Scudder 2008). As Bosshard and Golzimer (2005: 4) put it, 'resettlement and compensation plans have had a nearly universal record of failure, almost always failing to restore, much less improve, the livelihoods of affected populations'. Similarly, the World Commission on Dams (2000: 4) observe that the 'lack of equity in the distribution of benefits has called into question the value of many dams in meeting water and energy development needs when compared with the alternatives'. Resettlement directly contributes to poverty, the impact of displacement can include loss of land, joblessness, homelessness, marginalization, food insecurity, increased health risks, social disarticulation, and the loss of civil and human rights (Cernea 1997; Downing 2002; Brown et al. 2008). Compensation rarely occurs, and when it does, it typically is insufficient to restore, let alone, improve quality of life for the displaced (Brown and Xu 2010). In China, for instance, Zhao et al. (2012) estimated that the net incomes of rural households displaced by dam building equaled only 53 percent of the national average.

2.3 Hydropower and economic growth

Rather than focusing on uneven development within countries (poverty), this hypothesis looks at rates of development between them (gross domestic product, or GDP), and it suggests that hydropower states could be prone to slower rates of economic growth, something important from the perspective of national policy. Salazar (2000: 173) writes that when done poorly, the negative economic impacts of dams can 'likely hinder the economic viability of the country as a whole.'

Proponents of this hypothesis suppose that there are several ways that hydropower projects can stymie economic development and lead to sluggish economic growth. One is by creating boom towns during construction that give the appearance of economic development on national indicators but fade away, once the project is completed (Cernea 2004). Another is that the stated goal of some hydropower projects is not to build a dam, but to promote foreign policy goals such as democracy promotion or the selling of arms (Lankester 2013). And Fox and Sneddon (2007) go so far as to argue that dam development is a way to subvert the global south by promoting development goals of industrialized nations. Another reason dams can degrade economic growth relates to some of their negative socio-environmental impacts (Holdren and Smith 2000: 79; Burke et al. 2009; Valença et al. 2007; Adams et al. 1986; Lerer and Scudder 1999) that can be monetized into economic losses. One such effect concerns accidents at dams and their effects on social, economic, and political stability when they fail. One study looking at global energy accidents over one hundred years found that while hydroelectric dams were responsible for fewer than 1 percent of total energy accidents by frequency, they claimed 94 percent of reported fatalities and entailed $9.7 billion in damages (in $2007) (Sovacool 2008).

There are other ways that dams potentially interfere with economic growth. For instance, many of the revenues from hydropower construction or operation flow out of national economies to foreign investors. In addition, hydropower projects can create a lag in a nation’s per capita income. In China, greater hydropower development has, perhaps ironically, led to social displacement and blackouts for consumers as industrial customers use the bulk of the electricity generated (Ma 2011; McNally et al. 2009). Similarly, in Europe, hydropower facilities have been prone to non-optimal management:

reservoirs are depleted, leading to lower overall efficiency and, by extension, to sub-optimal economic impact (Lehner et al. 2005).

2.4 Hydropower and debt

This hypothesis holds that cost overruns and diseconomies of scale frequently associated with hydropower projects are corrosive to fiscal discipline. Flyvbjerg (quoted in Leslie 2014: 2) states, ‘For many countries, the national economy is so fragile that the debt from just one mega-dam can completely negatively affect the national economy’. Merrow et al. (1988: 2-3) warn that ‘such enormous sums of money ride on the success of megaprojects … that company balance sheets and even government balance-of-payments accounts can be affected for years by the outcomes’. For example, the 44,000 MW Grand Inga Dam being built in the Democratic Republic of the Congo, will cost $80 billion (Green et al. 2015), more than twice the country’s annual GDP.

The historical record seems to confirm this hypothesis. One recent study used reference class forecasting to assess the outcomes and costs of 245 dams—186 of them hydroelectric —built between 1934 and 2007 across five continents and 65 countries and collectively involving more than $353 billion of investment (Ansar et al. 2014). The study found ‘overwhelming evidence that budgets are systematically biased below actual costs of large hydropower dams’ and that ‘actual costs were on average 96% higher than estimated costs’. The authors highlighted that these cost-overrun figures are exceptionally conservative, as they *exclude* inflation, substantial debt servicing, and other environmental and social factors. A series of follow-up studies of 401 electricity infrastructure projects around the world also concluded that cost overruns afflicted 75.4 percent of the hydroelectric projects in the sample and that these exhibited a mean cost escalation of 70.6 percent per project (Sovacool et al. 2014a; Sovacool et al. 2014b). As Table 3 indicates, compared to other types of infrastructure, only nuclear reactor construction is more susceptible to cost escalation than hydropower projects are.

Table 3: Mean Cost Escalation for Various Infrastructure Projects

Technology	Mean Cost Overrun Escalation (% project budget)	(n) for the sample
Nuclear reactors	117	180
Hydroelectric dams	71	61
Railway networks	45	58
Bridges and tunnels	34	33
Roads	20	167
Mining Projects	14	63
Thermal Power Plants	13	36
Wind Farms	8	35
Transmission Projects	8	50
Solar Farms	1	39

Source: Sovacool et al. (2014c).

There are several reasons why hydropower projects are so prone to exhibit cost overruns and debt. Their construction is technically complex, and involves unique elements, such as the need to build coffer dams and excavate large amounts of subsurface rocks, often resulting in unexpected costs during construction (World Commission on Dams 2000). Dams are also prone to excessive construction delays: in their study of electricity infrastructure, Sovacool et al. (2014a) calculated a mean construction time of 118 months for hydroelectric dams. Many countries need to take out loans to finance their construction. Leslie (2014: 3) argues that they ‘consume large chunks of developing countries’ financial resources, as dam planners underestimate the impact of inflation and currency depreciation’, and that ‘many of the funds that support large dams arrive as loans to the host countries, and must eventually be paid off in hard currency’.

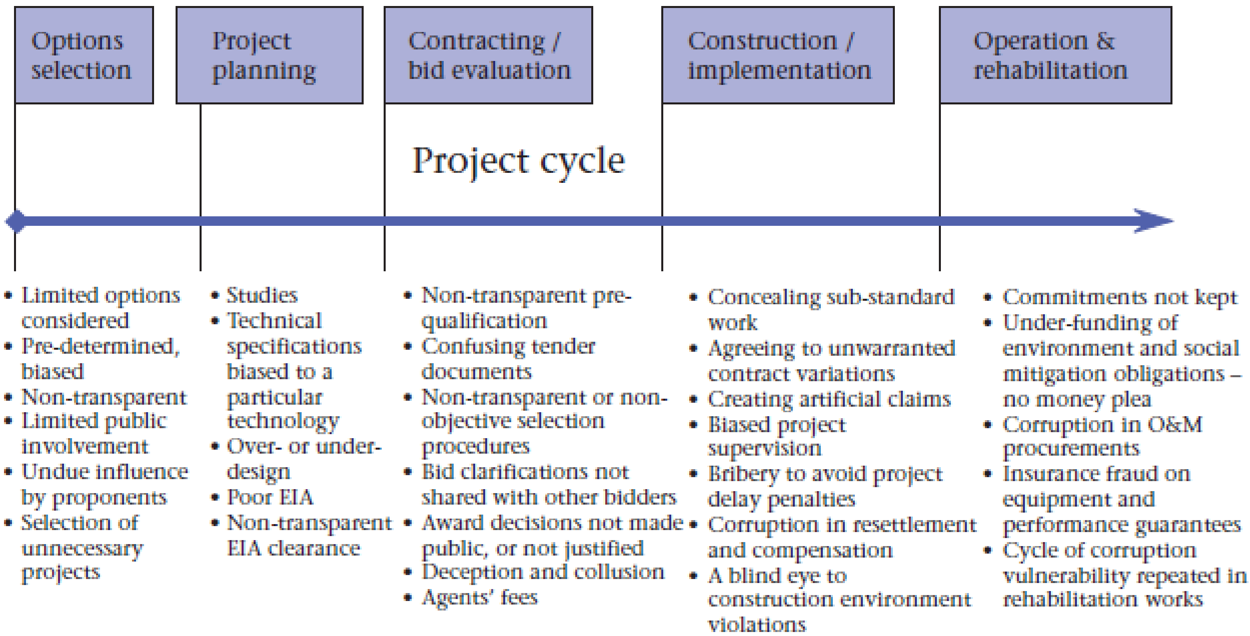
2.5 Hydropower and corruption

This hypothesis is that hydropower projects facilitate corruption. As Transparency International (2008: xxv) explains:

> The hydropower sector's massive investment volumes and highly complex, customized engineering projects can be a breeding ground for corruption in the design, tendering and execution of large-scale dam projects around the world. The impact of corruption is not confined to inflated project costs, however. Large resettlement funds and compensation programs that accompany dam projects have been found to be very vulnerable to corruption, adding to the corruption risks in the sector.

The World Commission on Dams (2000: 6) reached a similar conclusion when they wrote that 'decision-makers may be inclined to favor large infrastructure as they provide opportunities for personal enrichment not afforded by smaller or more diffuse alternatives.' Butterworth and Harpe (2009: 1) conclude that 'multimillion dollar water infrastructure projects carry some of the largest corruption risks in the sector' and that 'the potential for grand corruption in big dam projects and upgrading urban water and sanitation systems can be so significant as to skew policy making towards the most lucrative investments.' In Figure 1, Haas (2008) illustrates how corruption can occur at every stage in the hydropower project cycle.

Figure 1: Corruption Risks and the Hydropower Project Cycle



Source: Haas 2008

There are many strong arguments in favor of the corruption hypothesis, even if precise assessments are, predictably, difficult to achieve. Haas (2008) estimates that corruption in the hydropower sector accounts for $5–6 billion of lost revenue each year. This, however, may be overly conservative. Plummer (2008) offers the 'best-case scenario' that corruption siphons off 10 percent of the budget of all infrastructure and that, at worst, 30 percent disappears. Given that the World Economic Forum reports that global spending on infrastructure amounts to about $2.7 trillion each year (Economist 2014), the price tag for corruption ranges from $270 billion to $810 billion. The World Bank (2013) offers a 'conservative estimate' of $1 trillion in annual worldwide bribery—only one type of corruption. The complexity of dam building can generate a lack of accountability and opaque project management (Bossard et al. 2008). For example, there may be separate contracts for equipment, civil works, materials, construction, management, as well as for external consultancies involving local, national, and international actors, each with their own requirements. Resettlement activities that involve large sums of money can also create opportunities for graft (Scudder 2008; Sohail and Cavill 2007).

The historical record of numerous cases supports these concerns. In Lesotho, Indonesia, Thailand, and Kenya, dam builders used ‘corrupt practices’ to acquire reservoir sites that were reserved for indigenous people or impinged on protected national wildlife refuges (Scudder 2008). Government officials reportedly stole $50 million of resettlement funds appropriated for the Three Gorges Dam in China, leading to ‘the largest such corruption scandal on record’ (Haas 2008: 98). Costs for the Yacyretá Dam between Argentina and Paraguay ballooned by $2.7 billion, due to bribes and misappropriation of funds (Sohail and Cavill 2007). In Malaysia, Sarawak Energy has been accused of granting $200 million worth of hydropower contracts to companies linked directly to the Chief Minister’s family (Bruno Manser Fund 2013).

2.6 Hydropower and environmental degradation

To those outside of the hydropower sector, our final hypothesis may seem counterintuitive, but the act of building (and maintaining) a dam can be an energy-intensive and greenhouse gas emissions-intensive process. Dams can also produce a range of noxious environmental impacts, many of them with negative implications on sustainability and climate change. For instance, land clearing and deforestation during dam construction, flooding and greenhouse gas emissions from reservoirs, changes in hydrology and water quality, and the impacts from downstream uses (such as aluminum smelting) can all lead to negative climatic or environmental effects.

In terms of climate change and greenhouse gas emissions specifically, Gagnon and Vate (1997) accounted for emissions (direct and indirect) embodied in the construction of hydroelectric dams as well as emissions from decaying biomass from flooded land in reservoirs. Although they found that in "most cases" hydropower's carbon footprint was better than fossil fuels, this was not always true, especially in tropical climates where reservoir emissions could be "very high." Fearnside (2004: 8) examined emissions profiles dams and noted that, due to the large volume of water (and dissolved biomass) that reservoirs contain, they:

> become virtual methane factories, with the rise and fall of the water level in the reservoir alternately flooding and submerging large areas of land around the shore; soft green vegetation quickly grows on the exposed mud, only to decompose under anaerobic conditions at the bottom of the reservoir when the water rises again. This converts atmospheric carbon dioxide into methane, with a much higher impact on global warming.

Such methane is released as reservoirs are drawn down in times of drought or greater need for electricity, as well as in smaller amounts during ordinary operation as water flows over the turbines and spillway. In Brazil, the 8,370 MW Tucuru Dam in the Amazon produces more greenhouse gases than Brazil's largest city, São Paulo; and another dam upriver generates 11.2 million tons of carbon per year, equivalent to the annual emissions of 2.3 million cars (Fearnside 2002). Other studies have confirmed these findings, namely that the carbon footprint or lifecycle impact of a dam can vary greatly depending on design, location and climate, maintenance, and lifetime of operation (among other factors) (World Commission on Dams 2000; Vate 1997; Raadal et al. 2011).

These sorts of emissions releases are separate from a variety of other veritable factors that can negatively impact the environment (and lead to higher emissions profiles). In Malaysia, for example, construction of the 2,400 MW Bakun Dam necessitated the land clearing and deforestation of 1.5

million hectares of land, a size larger than the country of Singapore (Choy 2005a). It also resulted in access roads built to the dam that 'opened up' entire tropical forests to logging and poaching (Sovacool and Bulan 2011). As one expert noted, Bakun 'has massive climate impacts for it essentially took a huge sink of carbon dioxide, a primary forest, and converted it to a source of methane and other greenhouse gases, emissions so large that they are likely equivalent to all of the emissions from Malaysia's coal-fired power plants' (Sovacool and Bulan 2011: 4856).

Table 4 summarizes other negative impacts that hydroelectric dams can have on habitats, water quality, and environmental sustainability. Both Brismar (2004) and Wang et al. (2013) warn that much of the time, only lower order impacts at a single dam are evaluated, whereas in reality, lower- and higher-order impacts occur and they can cascade across multiple dams—meaning impact assessments can underestimate the true extent of environmental damage. Kibler and Tullos (2013) further suggest that the cumulative effects (in terms of habitat destruction) of many small dams can outweigh those of one large dam. Separate still from these direct environmental impacts are the various processes and purposes for which hydroelectricity is put to use. If utilized for industrial manufacturing and aluminum smelting, for instance, then downstream emissions can be significant, with a single aluminum smelter emitting volumes of carbon dioxide, hydrogen fluoride, silicon tetrafluoride, and solid particles similar to those of a coal-fired power station (Choy 2005b).

Table 4: Negative Environmental Impacts from Hydroelectric Dams

Stage	Environmental Impact
Clearing and Construction	Increased water turbidity
	Loss of pool nursery habitat
	Reduced organic input
	Impaired migration of fish
	Embodied emissions in materials (concrete, steel)
	Greenhouse gas emissions from land clearing

Impoundment	Reduced river flow, turbidity, and organic input
	Loss of habitat due to reduced water depth
	Reduced reservoir turbidity
	Increased phytoplankton production
	Impaired fish migration
	Replacement of natural riverine habitat with artificial deep lake habitat
	Greenhouse gas emissions from reservoirs
Operation	Reduced river turbidity
	Reduced river dissolved oxygen content
	Increased hydrogen sulphide
	Impaired fish migration
	Altered upstream species composition
	Replacement of native riverine species with lake-adapted species in reservoir
	Need for fossil-fuelled backup power during unplanned outages of maintenance
Decommissioning	Embodied emissions in decommissioning activities
	Changes in land use for remediation

Source: Authors' compilation from Holdren and Smith (2000: 79); International Hydroelectric Association (2003: 14); Manyari and Carvalho (2007); Sovacool and Bulan (2011); Wang et al. (2012)

3. Research Design and Analysis

This section of the paper briefly describes how we tested our hypotheses, presenting the metrics that function as dependent variables and giving an overview of and justification for our research design. As we will explain, the core of our assessment is testing three reference classes of countries: 'major hydropower countries' (which generate 70% or more of their national electricity supply from hydroelectric dams), 'OPEC countries', and all remaining 'non-hydro and non-OPEC countries'.

We decided that countries served as our best unit of analysis, rather than individual dams or hydropower projects, or other types of actors such as transnational firms or governance networks. This is because 'the nation state remains where most energy planning and policymaking takes place, and it is also how most major energy statistics are collected, based on national boundaries' (Brown et al. 2014: 5). In addition, notwithstanding 'new modes of governance' above and below countries (Florini and

Sovacool 2009), a majority of important political decisions are still made at the state level, and the state-based international system has demonstrated a high degree of coherence (Falkner 2013). Countries also hold significant positive potential in their ability to address major challenges such as climate change and energy transitions (Johnstone and Newell 2018). As such, Eckersley (2004: iv) calls states the 'gatekeepers of the global order,' and adds that they remain the 'preeminent political institution for addressing environmental problems.'

3.1 Choosing metrics and dependent variables

Our first step was to select country metrics and data to correspond with each of our six hypotheses. As Table 5 summarizes, to measure conflicts we relied on the UCDP database from Uppsala; for poverty, we chose the 'poverty gap', a measure that reflects both the depth and incidence of poverty; for economic growth, we selected GDP per capita; and we investigated total debt stocks to evaluate debt. For corruption, we depended on the World Bank's Worldwide Governance Indicators dataset as this data draws from more sources and offers a greater range of dates than the Corruption Perceptions Index from Transparency International (World Bank 2017b). For environmental degradation, we selected the metric greenhouse gas emissions per capita.

Table 5 Hydropower Security and Development Hypotheses and Metrics

Hypothesis	**Metric**	**Definition**	**Range**	**Source**
Hydropower increases internal conflict.	number of internal conflicts	A contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least twenty-five battle-related deaths	1985-2014	UCDP/PRIO (2017); Themnér, Lotta & Peter Wallensteen (2014), Conflict types 3 and 4
Hydropower increases poverty.	Poverty gap at $1.90 a day	Mean shortfall from the poverty line (counting the non-poor as having zero	1985-2014	World Bank (2017a)

	(PPP) (%)	shortfall), expressed as a percentage of the poverty line		
Hydropower decreases economic growth rates.	GDP per capita ($)	Gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars.	1985-2014	World Bank (2017a)
Hydropower increases rates of public debt.	External debt stocks (% of GNI)	Total external debt is debt owed to nonresidents repayable in currency, goods, or services. Total external debt is the sum of public, publicly guaranteed, and private nonguaranteed long-term debt, use of IMF credit, and short-term debt. Short-term debt includes all debt having an original maturity of one year or less and interest in arrears on long-term debt. GNI (formerly GNP) is the sum of value added by all resident producers, plus any product taxes (less subsidies) not included in the valuation of output, plus net receipts of primary income (compensation of employees and property income) from abroad.	1985-2014	World Bank (2017a)
Hydropower increases corruption.	Control of corruption	Reflects perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as ‘capture’ of the state by elites and private interests.	1996-2014	World Bank (2017b).
Hydropower increases greenhouse gas emissions	Total greenhouse gas emissions (in tons of CO_2 equivalents per capita)	This metric is composed of CO_2 totals excluding short-cycle biomass burning (such as agricultural waste burning and Savannah burning) but including other biomass burning (such as forest fires, post-burn decay, peat fires and decay of drained peatlands), all anthropogenic CH_4 sources, N_2O sources and F-gases (HFCs, PFCs and SF_6), divided by the average total population per country.	1985-2012	World Bank (2017a)

Source: Compiled by the authors.

3.2 Research design and country reference groups

An empirical analysis of the effect of hydropower on security, economic, development and environmental indicators confronts three major challenges. First, the effects of hydropower dams independent from generation – such as construction, design, excavation, building, and financing – are distinct from the those of hydropower electricity production, which deals with operating and maintaining an electric power plant. Second, the long timeframe, missing data and presumed high variability of the exact onset of hydropower effects make analysis challenging. And third, various other variables that influence economic and development indicators in a country (e.g., a government's commitment to democratic values), could cloud the relationship between hydropower and performance on our indicators.

The design of our research was specifically chosen to account for these three challenges. We relied heavily on both method and data triangulation techniques to increase the reliability and validity of our research findings (for an overview, see Hussy et al. 2010). Regarding data triangulation, we chose three long timeframes over 30 years (timeframe 1: 1985-1994; timeframe 2: 1995-2004; timeframe 3: 2005-2014) and calculated the average score per dependent variable and country for each of these two timeframes. Thus, we were able to counter the challenge of missing data points (of which there were many) and to conduct our analysis of the three periods separately.

Regarding method triangulation, we conducted two separate analyses to test our six hypotheses per timeframe. First, we conducted a comparative country analysis to analyze the differences in the selected six dependent variables between (1) countries high in hydropower production (electricity supply), (2) non-hydro countries (countries which are not part of group 1 and group 3), and (3) members of OPEC. Country classes were mutually exclusive, and whenever a country may have fit into two classes (e.g., Gabon and Venezuela), it was placed in the hydropower reference class. We selected OPEC countries, rich in oil and gas, in addition to non-hydropower countries to see whether hydropower states outperformed those traditionally associated with the 'resource curse' (Robinson et al. 2006; Hammond 2011). Van de Graaf and Bradshaw (2018) also note how oil exporting countries, many of which belong to OPEC, face some collective and daunting challenges on the horizon as a new world order emerges where oil is replaced by natural gas and threatened by peaks in demand.

Table 6 gives an overview of countries and inclusion criteria for each of the three country classes in the three timeframes. For hydropower state classification, one dataset of the World Bank was used (World Bank 2017a): electricity production per country and year from hydroelectric sources as a percentage of energy from all sources. In the first timeframe, our data analysis encompassed 113 countries, followed by 137 countries in timeframe 2 and 140 countries in timeframe 3, with lower case numbers due to missing data, mostly related to islands or microstates. To put these numbers in perspective, the United Nations currently has 193 member states. Nonetheless, the countries included in our analysis still account for 91.6% of the world population in timeframe 1, 96.2% of the world population in timeframe 2 and 96.0% of the world population in timeframe 3, respectively. We used the non-parametric Wilcoxon rank-sum test to analyze the differences between the three country classes, since some groups were quite small, and this test yields more robust results than the parametric t-test. For hypothesis testing, we focused on significant differences between hydropower countries and non-hydropower countries. Findings derived from the comparison of hydropower countries with OPEC countries were treated as additional, more anecdotal evidence.

Table 6: Definition of three country reference groups

Country reference group	Timeframe 1 1985-1994	Timeframe 2 1995-2004	Timeframe 3 2005-2014
Hydropower countries: *Countries with a hydropower electricity production rate > 70% in previous year to timeframe*	*25 total* Angola, Albania, Brazil, Chile, Cameroon, Congo (Dem. Rep.), Congo (Rep.), Costa Rica, Ecuador, Ethiopia, Gabon, Ghana, Honduras, Iceland, Kenya, Sri Lanka, Norway, Nepal, New Zealand, Peru, Paraguay, Tanzania, Uruguay, Zambia, Zimbabwe	*33 total* Angola, Albania, Brazil, Cameroon, Congo (Dem. Rep.), Congo (Rep.), Costa Rica, Ecuador, Ethiopia, Ghana, Honduras, Iceland, Kenya, Sri Lanka, Norway, Nepal, New Zealand, Peru, Paraguay, Tanzania, Uruguay, Zambia, Venezuela, Colombia, Haiti, Mozambique, Panama, Vietnam, Bosnia and Herzegovina, Kyrgyz Republic, Latvia, Namibia, Tajikistan	*23 total* Angola, Albania, Brazil, Cameroon, Congo (Dem. Rep.), Congo (Rep.), Costa Rica, Ethiopia, Ghana, Iceland, Norway, Nepal, Peru, Paraguay, Uruguay, Zambia, Venezuela, Colombia, Mozambique, Kyrgyz Republic, Namibia, Tajikistan, Georgia
OPEC countries: *Countries which are members of OPEC for the whole timeframe and which are not hydropower countries*	*11 total* United Arab Emirates, Algeria, Indonesia Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, Venezuela	*10 total* United Arab Emirates, Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia	*9 total* United Arab Emirates, Algeria, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia
Non-hydropower countries: *All countries which do not fit the criteria of hydropower and OPEC countries*	*77 total* Argentina, Australia, Austria, Belgium, Benin, Bangladesh, Bulgaria, Bahrain, Bolivia, Brunei Darussalam, Botswana, Canada, Switzerland, China, Cote d'Ivoire, Colombia, Cuba, Curacao, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Egypt, Spain, Finland, France, United Kingdom, Gibraltar, Greece, Guatemala, Hong Kong, Haiti, Hungary, India, Ireland, Israel, Italy, Jamaica, Jordan, Japan, Korea, Lebanon, Luxembourg, Morocco, Mexico, Malta, Myanmar, Mozambique, Mauritius, Malaysia, Nicaragua, Netherlands,	*94 total* Chile, Gabon, Zimbabwe, Argentina, Australia, Austria, Belgium, Benin, Bangladesh, Bulgaria, Bahrain, Bolivia, Brunei Darussalam, Botswana, Canada, Switzerland, China, Cote d'Ivoire, Cuba, Curacao, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Egypt, Spain, Finland, France, United Kingdom, Gibraltar, Greece, Guatemala, Hong Kong, Hungary, India, Ireland, Israel, Italy, Jamaica, Jordan, Japan, Korea, Lebanon, Luxembourg, Morocco, Mexico, Malta, Myanmar, Mauritius, Malaysia, Nicaragua, Netherlands, Oman, Pakistan, Philippines, Poland, North Korea, Portugal, Romania, Sudan, Senegal, Singapore, El Salvador, Slovak Republic, Sweden, Syria, Togo, Thailand, Trinidad and Tobago,	*108 total* Ecuador, Honduras, Kenya, Sri Lanka, New Zealand, Tanzania, Haiti, Panama, Vietnam, Bosnia and Herzegovina, Latvia, Indonesia, Chile, Gabon, Zimbabwe, Argentina, Australia, Austria, Belgium, Benin, Bangladesh, Bulgaria, Bahrain, Bolivia, Brunei Darussalam, Botswana, Canada, Switzerland, China, Cote d'Ivoire, Cuba, Curacao, Cyprus, Czech Republic, Germany, Denmark, Dominican Republic, Egypt, Spain, Finland, France, United Kingdom, Gibraltar, Greece, Guatemala, Hong Kong, Hungary, India, Ireland, Israel, Italy, Jamaica, Jordan, Japan, Korea, Lebanon, Luxembourg, Morocco, Mexico, Malta, Myanmar, Mauritius, Malaysia, Nicaragua, Netherlands, Oman, Pakistan, Philippines, Poland, North Korea, Portugal,

	Oman, Pakistan, Panama, Philippines, Poland, North Korea, Portugal, Romania, Sudan, Senegal, Singapore, El Salvador, Slovak Republic, Sweden, Syria, Togo, Thailand, Trinidad and Tobago, Tunisia, Turkey, United States, Vietnam, Yemen, South Africa	Tunisia, Turkey, United States, Yemen, South Africa, Armenia, Azerbaijan, Belarus, Eritrea, Estonia, Georgia, Croatia, Kazakhstan, Cambodia, Lithuania, Moldova, Macedonia, Mongolia, Russia, Serbia, Slovenia, Turkmenistan, Ukraine, Uzbekistan	Romania, Sudan, Senegal, Singapore, El Salvador, Slovak Republic, Sweden, Syria, Togo, Thailand, Trinidad and Tobago, Tunisia, Turkey, United States, Yemen, South Africa, Armenia, Azerbaijan, Belarus, Eritrea, Estonia, Croatia, Kazakhstan, Cambodia, Lithuania, Moldova, Macedonia, Mongolia, Russia, Serbia, Slovenia, Turkmenistan, Ukraine, Uzbekistan, Niger, Suriname, Kosovo

Source: Compiled by the authors.

Second, we conducted a linear regression analysis per hypothesis and timeframe with hydropower production rate per country as an independent variable. This analysis gives an idea of whether hydropower production is correlated with the selected metrics over *all* countries, how this correlation is pronounced (positively or negatively), and how much variance hydropower can explain in the six dependent variables.

In sum, our research design allowed us to conduct six tests per hypothesis: the difference in the research variable between hydropower producing countries and non-hydropower countries in the three timeframes 1985-1994, 1995-2004 and 2005-2014, and the effect of the hydropower production rate on the research variables in the three timeframes 1985-1994, 1995-2004 and 2005-2014. For control of corruption, only four hypotheses could be tested, since there was no data available for timeframe 1. In accordance with Field (2009: 57), we treat r = .1 (R^2 = .01) as the threshold for a small effect or association/correlation, r = .3 (R^2 = .09) as the threshold for a medium effect or association/correlation, and r = .5 (R^2 = .25) as the threshold for a large effect or association/correlation. The significance level for all tests was set to $p < .05$ (2-sided).

3.3 Limitations

Admittedly, our research design has some drawbacks. Many of the security, poverty, development, and governance issues we examine occur at local levels, yet our analysis focuses entirely at the level of the nation state. There are two reasons for this decision: First, data for most countries was available only on a national basis, and second, we wanted our study to move beyond the kind of isolated local case studies that so dominate the literature we reviewed. Moreover, we maintain that for our hypotheses to be true among a variety of major hydropower states (those relying on dams to generate at least 70 percent of their electricity), such infrastructure would have to be spread across large enough parts of each state to have a meaningful effect on national trends and statistics. In addition, our analysis may not capture the harms inflicted on downstream countries affected by, but not benefiting from, the upstream country building the dam: e.g. the entire eastern Mediterranean has been affected by Egypt's High Aswan Dam, or the damage from upstream Chinese dams on downstream communities in the Mekong region.

Furthermore, our analysis allows for only correlative interpretations regarding the relationship between hydropower production and governance, economic development, and environmental metrics. This is primarily because we did not include other factors that might affect these relationships, such as specific characteristics of political systems, national and local regulations, different domestic energy needs and energy portfolios, and other development indicators such as literacy or public health. Herein lies a problem common to the use of data sets of quantified or dichotomized variables: George and Bennett (2005: 44) note that they can 'achieve reproducible results across many cases (external validity) but only at the cost of losing some of the ability to devise measures that faithfully represent the variables that they are designed to capture (internal validity).' Last, our analysis focuses on hydropower electricity production and not construction rates, meaning that the effects of operating dams on the dependent variables are displayed, not the effect of constructing dams. An analysis which includes hydropower construction rates and their effect on governance and economic metrics can be found in Sovacool & Walter (2018). However, that analysis ended with 2010 data, looked at difference reference classes of countries, and did not examine all of the hypotheses investigated here.

4. Results and Discussion

This section of the paper presents the results of the empirical analyses we conducted in relation to each of our six hypotheses, namely examining whether (1) hydropower increases internal conflict, (2) hydropower increases poverty, (3) hydropower decreases economic growth rates, (4) hydropower increases rates of public debt, (5) hydropower increases corruption, and (6) hydropower increases greenhouse emissions.

As this section will demonstrate, our analysis of key country metrics from 1985 to 2014 produces mixed results with regards to the hypotheses. Table 7 gives an overview of the results per hypotheses, Table 8 the results of the regression analyses. While results are only included if they reach significance, it is interesting to note that the trend (direction) of all conducted tests in the three timeframes for hypotheses 1-5 is always in line with what our hypotheses would suggest, with exception of only two cases (namely the difference in internal conflicts (timeframe 1) and external debt stock (timeframe 3) between hydropower countries and non-hydropower countries).

Table 7: Summary of hypotheses tests

Dimension	**Hypothesis**	**Results**	
		Wilcoxon rank-sum test	Regression analysis
Internal Conflict	Hydropower increases conflict.	Not supported	Not supported
Poverty	Hydropower increases poverty.	Partially supported (timeframe 2 and 3)	Partially supported (timeframe 2 and 3)
Development	Hydropower decreases economic growth rates.	Supported (all timeframes)	Partially supported (timeframe 2 and 3)
Fiscal responsibility	Hydropower increases rates of public debt.	Partially supported (timeframe 2)	Partially supported (timeframe 2)
Governance	Hydropower increases corruption.	Partially supported (timeframe 2)	Partially supported (timeframe 2)
Environmental degradation	Hydropower increases greenhouse gas emissions.	Not supported	Not supported

Source: Authors.

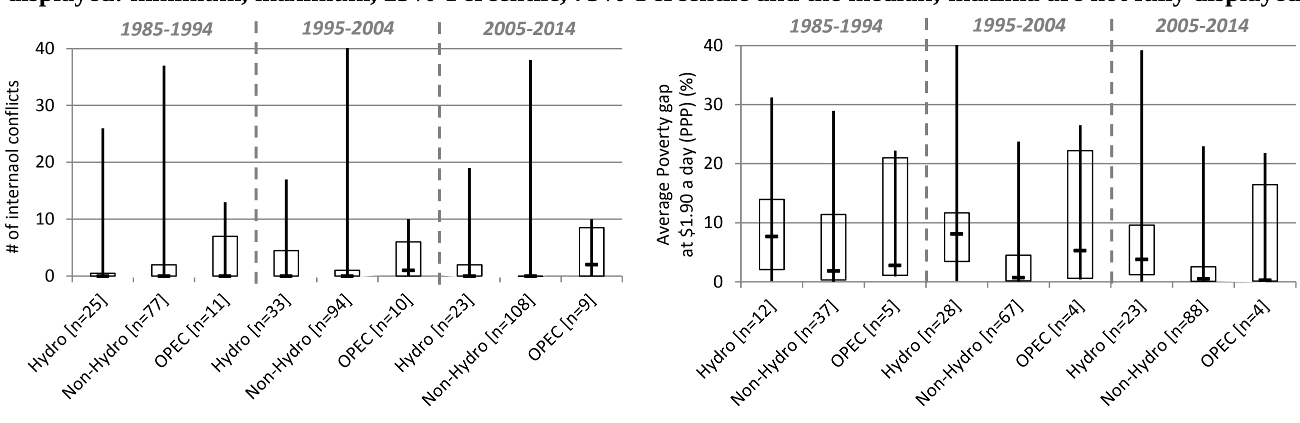
Table 8: Summary of conducted regression analyses

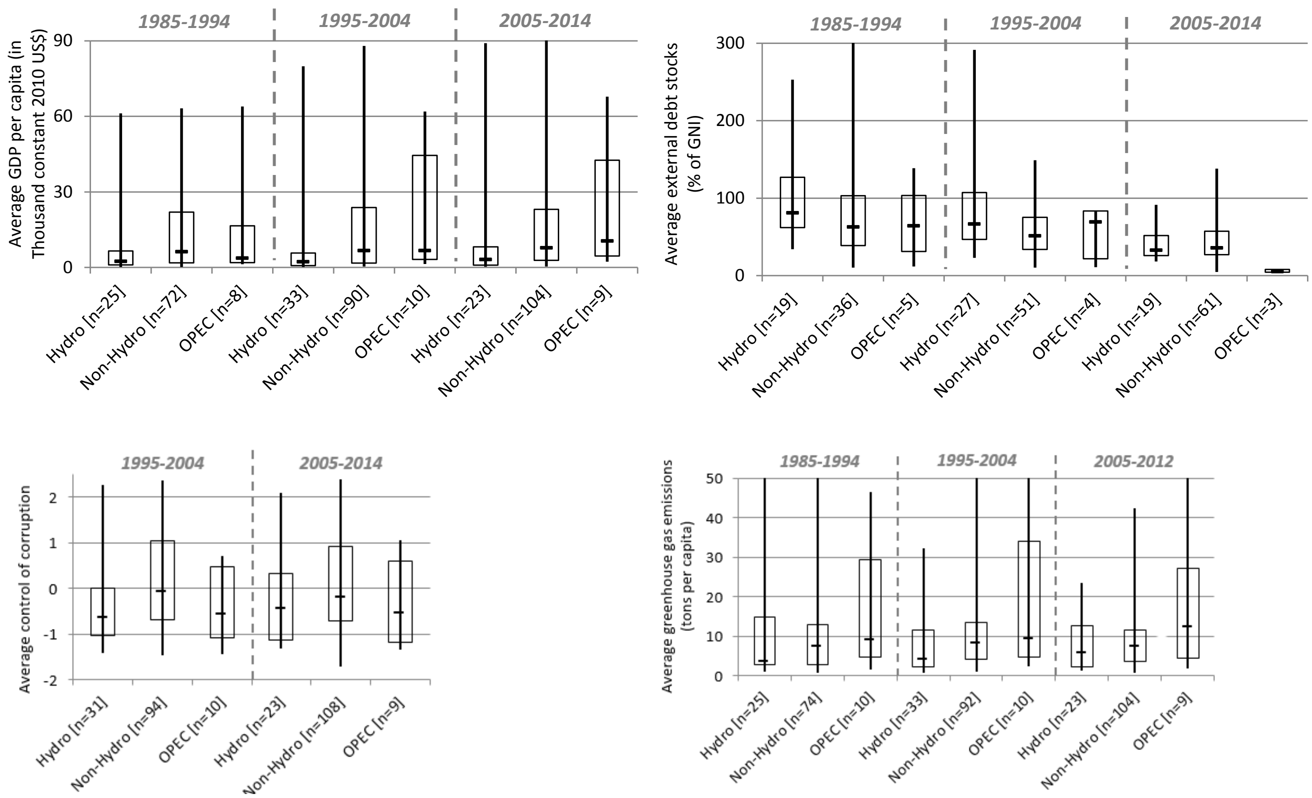
Dependent Variables		Timeframe 1 1985-1994	Timeframe 2 1995-2004	Timeframe 3 2005-2014
Number of conflicts	β	.08	.07	.02
	R^2	.01	.01	.00
	N	113	136	140
Poverty Gap	β	.21	**.37*****	**.38*****
	R^2	.04	**.14**	**.14**
	N	54	**99**	**115**
GDP per capita	β	-.18	**-.21***	**-.18***
	R^2	.03	**.04**	**.03**
	N	105	**132**	**136**
External debt stocks	β	.11	**.39*****	.04
	R^2	.01	**.15**	.00
	N	60	**81**	83
Control of Corruption	β	-	**-.24****	-.16
	R^2	-	**.06**	.03
	N	-	**134**	140
Greenhouse gas emissions per capita	β	-.05	**-.19***	**-.19***
	R^2	.00	**.04**	**.04**
	N	109	**134**	**136**

Independent variable: hydropower electricity production in previous year to timeframe; * $p < .05$; ** $p < .01$; *** $p < .001$; significant results in bold; Source: Authors

We can tentatively summarize our results as follows: Hypotheses 1 and 6 are not supported by the data analysis. It seems that hydropower electricity production does not increase the number of internal conflicts a country experiences, and actually reduces greenhouse gas emissions per capita. All other hypotheses find partial support in the data: It seems that hydropower increases to some extent poverty, GDP per capita, public debt and corruption. Regarding hypotheses 2 to 5, 13 out of 22 (59.1%) conducted tests yielded significant results in line with our hypotheses. It is especially noteworthy that we found that hydropower influences a country's governance, economic and development indicators significantly—even though it plays such a small part of the respective countries' economies. In the following section, a detailed description of the results per hypotheses is given. Figure 2 summarizes our findings in the form of boxplots.

Figure 2: Boxplots of the six dependent variables in three country classes and three timeframes (per variable are displayed: minimum, maximum, 25%-Percentile, 75%-Percentile and the median; maxima are not fully displayed)





Source: Authors. Note: Due to data availability, control of corruption covers only the periods 1995 to 2004 and 2005-2014; data for greenhouse gas emissions in timeframe 3 only goes to 2012.

4.1 Hydropower and conflict

Our results, redrawn from the UCDP/PRIO Armed Conflict Dataset, do not support this hypothesis: While hydropower countries experienced more internal conflicts by trend than non-hydropower countries in timeframe 2 and 3 (see figure 2 above), none of these differences reaches significance (all $p > .05$). A similar picture emerges when applying regression analyses to the dataset (see table 8): While the hydropower production rate positively influences the number of experienced internal conflicts in all three timeframes, standardized coefficients and effect sizes are very small, and none of the effects reaches significance. When comparing hydropower countries to OPEC countries, it becomes clear that, while OPEC countries experienced more internal conflicts than hydropower countries in all three timeframes, once more none of these differences reaches significance (all $p > .05$).

4.2 Hydropower and poverty

Our empirical results partially support the hypothesis linking hydropower and poverty rates. While all effects were in line with the hypothesis by trend, only four out of six tests conducted showed significant results. As figure 2 reveals, hydropower countries have a higher poverty gap than non-hydropower countries in all timeframes. However, only the differences in timeframe 2 (W_s = 2 725.5, $z = -4.01$, $p < .001$, $r = -.41$) and timeframe 3 (W_s = 4 425.5, $z = -3.66$, $p < .001$, $r = -.35$) reach significance, yielding both medium effects. The application of regression analysis to the dataset lends further support to our finding (see Table 8 above). Hydropower production rates seem to have a pronounced positive effect on the poverty gap by trend. In timeframe 2 and 3, the effects become significant ($p < .001$), and yield medium effect sizes. As an additional finding, hydropower countries do also have a higher poverty gap than OPEC countries in all three timeframes; however, none of these differences reaches significance ($p > .05$).

4.3 Hydropower and economic growth

Our empirical findings partially support this hypothesis. From six conducted tests, five yielded significant results in line with our hypothesis, the last one only by trend. In all three analyzed timeframes, hydropower countries do have a lower GDP per capita than non-hydropower countries (see figure 2). All three differences reached significance and amounted to small-sized effects (timeframe 1: W_s = 936, z = -2.38, $p < .05$, r = -.24; timeframe 2: W_s = 1482, z = -3.22, $p < .01$, r = -.29; timeframe 3: W_s = 1070, z = -2.52, $p < .05$, r = -.22). With regards to the regression analysis, hydropower production rates had a negative effect on GDP per capita by trend in all three timeframes, however only the effects in the last two timeframes reached significance and yielded small effects (see Table 8). As an additional finding, hydropower countries did have a smaller GDP per capita than OPEC countries in all three timeframes; however, only the differences in timeframe 2 (W_s = 641, z = -2.44, $p < .05$, r = -.37) and timeframe 3 (W_s = 327, z = -2.20, $p < .05$, r = -0.39) reached significance and yielded medium effects.

4.4 Hydropower and debt

Our empirical findings only partially support this hypothesis: From six conducted tests, only two reached significant results in line with our hypothesis, and three further tests supported the hypothesis at least by trend. As can be seen in figure 2, hydropower countries do have a higher external debt stock than non-hydropower countries in timeframe 1 and 2, while for timeframe 3 the opposite is true. However, only the difference in timeframe 2 reached significance (W_s = 1797, z = -2.28, $p < .05$, r = -0.26) and yielded a small effect. Table 8, which is based on our regression analyses, adds some nuance to this finding: While the effect of the hydropower production rate on external debt stocks is in line with our hypothesis by trend in all three timeframes, only the effect in timeframe 2 reaches significance and amounts to a medium-sized effect. In addition, figure 3 shows that hydropower countries have higher external debt stocks than OPEC countries in all three timeframes. The difference in timeframe 3 even reached significance (W_s = 6, z = -2.73, p < .01, r = -0.58) and amounts to a large effect.

One possible explanation for why this hypothesis was only partially supported is that even though hydropower projects generate debt and suffer from overruns, in the long-run they pay off, in most cases, and show positive economic gains. Hydroelectricity supports lighting, communication, transport, commerce, manufacturing, industry, and agricultural productivity, though as the hypothesis about GDP shows, growth may be comparatively slower in hydropower countries than in non-hydro countries. Still, the IPCC have indicated that large hydropower projects can bring salient 'multiplier effects' of forty cents to a dollar for every dollar invested beyond the cost of the dam (Kumar et al. 2011). Yang (2003) has also calculated that in China every yuan invested into hydropower projects brings 5.13 yuan in generated GDP. Electricity makes so many things possible that some have even viewed its provision as a fundamental human right (Bradbook and Gardam 2006).

A second possible explanation is that hydropower dams seem costly in an absolute sense but are still better than some alternatives, notably nuclear power or fossil-fuels. Levent (2010) noted, for example, that in the absolute sense the construction of dams has had negative consequences for Turkey, but they were comparatively less polluting—and ultimately better for the economy—than the coal-fired power plants that could have been built. Moreover, not all of the countries in our major hydropower country class relied exclusively on large-scale, capital intensive dams—some, such as Nepal (Gippner et al. 2013), Tanzania (Adebayo et al. 2013) and Sri Lanka (Sovacool 2013), utilize smaller-scale, run-of-river designs that can operate without reservoirs. Multiplied in aggregate, such small and microhydro units can achieve all the generation capacity of large scale units, minimize opportunities for corruption, and when designed properly and well governed address environmental problems and increase developmental outcomes (Paish 2002).

4.5 Hydropower and corruption

Our data does partially support the hypothesis about a connection between hydropower and corruption. From four conducted tests, two yielded significant results in line with our hypothesis, the other two only by trend. Hydropower countries do have a lower value in the control of corruption index than non-hydropower countries in both timeframe 2 and timeframe 3 (timeframe 1 was not included in the analysis because the control of corruption index only started in 1996; see also figure 2). The difference in timeframe 2 reaches significance (W_s = 1520.5, z = -2.47, p < .05, r = -0.22) and amounts to a small effect. The same picture emerges in the regression analyses (see table 7): In both timeframes, the hydropower production rate has a negative effect on control of corruption, while only the difference in timeframe 2 reaches significance and yields a small effect size. An additional finding was that hydropower countries do score higher on the control of corruption index than OPEC countries in both timeframes, however none of the differences reaches significance.

4.6 Hydropower and environmental degradation

Our data does not support this hypothesis. As can be seen in Figure 2, hydropower countries do actually have *lower* greenhouse gas emissions per capita than non-hydropower countries in all three timeframes. However, all of these three differences fail to reach significance. The conducted regression analyses (see Table 8) yield similar findings: hydropower production rate had a negative effect on greenhouse gas emissions in all three timeframes, however only the effects in timeframe 2 and 3 reached significance and amounted to small effect sizes. The comparison of hydropower countries with OPEC countries yields a further, though not surprising nuance to these findings: As can be seen in Figure 2, in all three timeframes, hydropower countries do have lower greenhouse gas emissions than OPEC countries, however only the difference in timeframe 2 reaches significance and amounted to a medium effect size (W_s = 653, z = -2.01, $p < .05$, r = -.32).

Here, as with our hydropower and (financial) debt hypothesis, the carbon debt of a dam exists but is (slowly) paid off as the dam operates and/or displaces more carbon intensive forms of electricity supply. In a separate study looking at the energy payback ratio of different electricity systems, Gagnon (2008) estimated the ratio of total energy produced compared to the energy needed to build and operate an energy system. As Table 9 shows, he found that hydroelectric plants performed *the best* out of any source of electricity (save energy efficiency, which was not examined). So most dams pay back their energy (and carbon) debts quickly and for many years after. Nugent et al. (2014) also note that hydropower's lifecycle carbon footprint was the lowest among all sources of supply, even more competitive than low-carbon biomass, solar, and wind power. Then we have a list of other positive environmental attributes that can help offset the negative ones framing hypothesis 2.6: that dams can provide baseload power and thus displace coal or nuclear plants, that dams (with reservoirs) can also ramp up and down to meet flexible loads, that dams can balance and optimize intermittent renewable sources of energy and help integrate them into the grid, that dams have a long-lived life span (100 years or more) and comparatively low maintenance and operating costs, and that they produce no atmospheric pollutants and do not contribute to ambient air pollution. (International Hydroelectric Association 2003).

Table 9: Lifecycle energy payback ratios for various sources of electricity supply

Source	**Low estimate**	**High estimate**
Hydropower with reservoir	205	280
Run of river hydropower	170	267
Onshore wind power, 35% use factor	18	34
Biomass wastes	-	27
Biomass plantation	3 (hauled 100 km)	5 (hauled 20 km)
Solar photovoltaic	3	6
Nuclear, conventional Pressurized Water Reactor	14	16
Natural gas, combined-cycle turbine; 55% efficiency	2.5 (transported 4000 km)	5 (near gas well)
Fuel cell, natural gas	1.5	3
Oil, conventional boiler; 35% efficiency	0.7 (Tar sands)	2.9 (conventional oil
Coal, conventional boiler; 35% efficiency; modern SO2 scrubbing	2.5 (transported 2000 km)	5.1 (transported 500 km)
Coal, conventional boiler; with CO2 capture and sequestration	1.6 (transported 2000 km)	3.3 (transported 500 km)

Source: Modified from Gagnon (2008)

5. Conclusion and Implications

To conclude, our statistical tests of six hydropower hypotheses gives varying results. While our data does not support the hypotheses that hydropower increases the number of internal conflicts a country experiences or an increase in greenhouse gas emissions per capita, the other four hypotheses find at least partial support in the data. In terms of poverty, from 1995-2004 and from 2005-2014, major hydropower states increased significantly their poverty gap and reduced significantly their GDP per capita. In addition, from 1995-2004 major hydropower states significantly increased external debt stocks and reduced significantly control of corruption. It is worthy to note that only for timeframe 1, which has the most missing data by far, no significant effects whatsoever in line with our hypotheses were found. In sum, when looking at the significant effects only, the hydropower production rate per country was able to explain between 4% and 15% of the variance of the four dependent variables poverty gap, GDP per capita, external debt stocks and control of corruption, which at country-level is surprising indeed. With these results in mind, we advance four separate conclusions.

First, the possible benefits of hydroelectricity—improved energy access, economic development, positive spillover effects, reduced carbon emissions—are real, but all too frequently, they are constrained. Although dams ostensibly are championed for their economies of scale and ability to bring about industrialization, our comparative assessment of different reference classes of countries suggest that major investments in hydropower do not result in gains greater than those made by OPEC and non-hydro countries. This finding potentially undermines the belief that supplying electricity via hydroelectric dams ought to be viewed primarily as a means to achieving economic development (or at least, GDP growth). Indeed, our study challenges the model that the GDP growth and per capita energy consumption offered from hydropower must go hand in hand and that the trickle-down benefits from industrialization and rapid economic growth will inevitably bring national competitive advantage.

Second, however, our analysis provides only partial support to our hypotheses, and thus suggests that hydroelectricity may not be necessarily as damaging as other sources of energy, notably fossil fuels. It may be that many of the single case studies from which we derived our hypotheses look at the very real consequences of dams in an absolute sense, detailing the incidence of their cost overruns or the severity and impacts of the increased poverty they impose on a population. These shortcomings of dams, though real, may pale in comparison to the deleterious effects of other policies, programs, and investments. Countries and their planners may simultaneously be erecting many other types of infrastructure and embarking on scores of other industrial projects. These other projects may degrade and marginalize people to a greater degree than hydropower dams, considering that countries that pursue hydroelectricity (compared to, say, nuclear power or coal) generally perform better on selected indicators, especially carbon footprints and energy payback ratios, than those that do not. And in some cases benefits of hydroelectric dams outweigh their costs, though these benefits may occur in urban areas far removed from the dam itself. Considerations of scale, scope, and temporality must be considered: Hydropower compared to what, and at what geographic scale? Major hydropower states compared to what types of countries? And, in what timeframe will costs and benefits unfold? Change either of these assumptions and you may alter the perception of hydropower. Hence the value of a cross-national and comparative approach is that it moves beyond single cases or isolated dam projects to focus on *international* dimensions.

Third, our data suggest that current calls for substantial, global investment in hydropower installed capacity and generation, including those from major institutions such as the International Energy Agency, IRENA, IPCC, and World Bank, must be closely scrutinized. The World Bank's particular support in recent years for large-scale hydropower as an aid in international development may be founded on mistaken assumptions regarding the long-range costs of given projects. Projects like the Bank-supported Grand Inga Dam in the Democratic Republic of Congo are all planned on a transformational scale, and designed in part for their speedy and far-reaching economic impact (Green et al. 2015). Our data suggest that energy and sustainable development programs must better recognize the complexity of possible tradeoffs when investing in hydropower and better recognize, and perhaps compensate, potential losers.

This brings us to our fourth and final conclusion: hydropower will likely remain a contested energy option for years to come, given the pronounced tradeoffs intrinsic to its adoption. Planners, investors, and analysts may need to rethink their underlying assumptions about how they evaluate hydropower's risks, advantages and feasibility in particular locations, including size, management, costs, and benefits, social and environmental impacts among them. Admittedly, local factors are important. For example, some projects may place their reservoirs in high mountain areas or remote deserts with no local populations to relocate and minimal impacts on the environment. Others, in low-lying riverbanks, may cause substantial risks to fisheries, flooding, and food security. Still others in may involve the inundation of highly valued land and the involuntary resettlement of thousands, or even millions, of people. As Koch (2002: 1209) surmises, many of these considerations are unique to hydropower, and they mean that 'the weighing of benefits against costs becomes difficult and often controversial, and high levels of social, environmental, technical, and political skills are required to plan, construct, and operate the project'.

However, such local factors also need contextualized at the national (and even international) scale. The answers to questions of whether 'hydropower is good for security' or 'development or any other benefit' are never predetermined, and require greater analysis from an IPE lens. We need to consider not only the magnitude of costs and benefits, but the equitable nature and timing of their distribution, and how they may flow within, between and beyond states. While our results suggest that hydropower dams do help in decarbonizing national economies, at least insofar as per capita carbon dioxide emissions fall, such a low-carbon pathway comes at a cost in terms of economic and sociopolitical tradeoffs. In sum: the political economy of hydroelectricity is also about national choices that are being made between which forms of (low carbon) electricity to invest in, and why. Which nations build dams, who benefits from them, and who suffers their costs—who wins and loses—must remain a central part of examining the promise—and peril—of hydropower.

6. References

Adebayo, E, BK Sovacool, and S Imperiale. "It's About Dam Time: Improving Microhydro Electrification in Tanzania," *Energy for Sustainable Development* 17(4) (August, 2013), pp. 378-385.

Adams, W. M., and Hughes, F. M. R. 1986. The environmental effects of dam construction in tropical Africa: Impacts and planning procedures, *Geoforum*, Volume 17, Issues 3–4, 403-410.

Ansar, Atif, Flyvbjerg, Bent, Budzier, Alexander, and Lunn, Daniel. 2014. Should We Build More Large Dams? The Actual Costs Of Mega-Dam Development. *Energy Policy*, Volume 69, June 2014, Pages 43-56.

Auty, Richard M. 1993. Sustaining Development in Mineral Economies: The Resource Curse Thesis. New York: Oxford University Press.

Baker, L et al. “The political economy of technological capabilities and global production networks in South Africa’s wind and solar photovoltaic (PV) industries,” Political Geography 60 (September, 2017), pp. 1-12.

Bakker, Karen. 1999. The politics of hydropower: developing the Mekong, *Political Geography* 18 209–232.

Bosshard, Peter, and Hildyard, Nicholas. 2008. Grand projects – grand corruption?, In *Global Corruption Report 2008: Corruption in the Water Sector* (Cambridge: Cambridge University Press, Transparency International, and Water Integrity Network), pp. 104-105.

Bradbrook, A. J., and Gardam, J. G. 2006. Placing Access to Energy Services Within a Human Rights Framework, *Human Rights Quarterly* 28, pp. 389– 415.

Brismar, Anna. Attention to impact pathways in EISs of large dam projects, *Environmental Impact Assessment Review*, Volume 24, Issue 1, January 2004, Pages 59-87

Brown, MA and BK Sovacool. *Climate Change and Global Energy Security: Technology and Policy Options* (Cambridge: MIT Press, 2011)

Brown, MA, Y Wang, BK Sovacool, and AL D’Agostino. “Forty Years of Energy Security Trends: A Comparative Assessment of 22 Industrialized Countries,” *Energy Research & Social Science* 4 (December, 2014), pp. 64-77.

Brown Philip H, Darrin Magee, and Yilin Xu. 2008. Socioeconomic vulnerability in China's hydropower development *China Economic Review* 19 (2008) 614–627

Burke, Michael, Jorde, Klaus, and Buffington, John M. 2009. Application of a hierarchical framework for assessing environmental impacts of dam operation: Changes in streamflow, bed mobility and recruitment of riparian trees in a western North American river, *Journal of Environmental Management*, Volume 90, Supplement 3, 224-236.

Butterworth, John, and de la Harpe, Jean. 2009. *Grand designs: Corruption risks in major water infrastructure projects* (International Water and Sanitation Centre, November).

Cernea, Michael M. 2004. Social Impacts and Social Risks in Hydropower Programs: Preemptive Planning and Counter-risk Measures. *Keynote address: Session on Social Aspects of Hydropower Development United Nations Symposium on Hydropower and Sustainable Development Beijing, China 27-29 October, 2004.*

Choy, Keong Yee. 2005a. "Energy Demand, Economic Growth, and Energy Efficiency – the Bakun Dam-Induced Sustainable Energy Policy Revisited." *Energy Policy* 33: 679-689.

Choy, Keong Yee. 2005b. "Dam-Induced Development and Environmental and Social Sustainability: The Bakun Industrialization Strategy Revisited." *Journal of Economic Issues* 39(1) (March): 123-150.

Colgan, Jeff D. Oil, Domestic Politics, and International Conflict, Energy Research & Social Science, Volume 1, March 2014, Pages 198-205

Colgan JD. Oil and revolutionary governments: fuel for international conflict. International Organization 2010;64:661–94

Di Muzio, Tim and Jesse Salah Ovadia (eds). Energy, Capitalism and World Order: Toward a New Agenda in International Political Economy.). Palgrave Macmillan. 2016.

Eckersley, R. 2004. *The green state: rethinking democracy and sovereignty*. (Cambridge: MIT Press).

Economist. 2014. Investing in infrastructure: The trillion-dollar gap. March 22.

Eissa, S. 2008. International law and hydro-hegemony in the Nile Basin: A Sudanese perspective. *Water Policy*, 10, pp. 29-49.

Falkner, R. 2013. The Nation-State, International Society, and the Global Environment, in *The Handbook of Global Climate and Environment Policy*, New York: Wiley & Sons, pp. 251–267

Field, A. 2006. *Discovering statistics using SPSS*. 3rd edition. (Los Angeles: Sage)

Fearnside, PM. 2002. Greenhouse Gas Emissions from a Hydroelectric Reservoir (Brazil's Tucuruí Dam) and the Energy Policy Implications. *Water, Air, and Soil Pollution January* 2002, Volume 133, Issue 1–4, pp 69–96

Fearnside, P.M. 2004. Greenhouse gas emissions from hydroelectric dams: Controversies provide a springboard for rethinking a supposedly "clean" energy source, *Climatic Change* 66(1-2): 1-8.

Florini, A. and B. K. Sovacool. 2009. Who governs energy? The challenges facing global energy governance, *Energy Policy*, vol. 37, no. 12, pp. 5239–5248.

Fox, C. A., and Sneddon, C. 2007. Transboundary river basin agreements in the Mekong and Zambezi basins: Enhancing environmental security or securitizing the environment? *International Environmental Agreements: Politics Law and Economics*, 7, 237–261

Gagnon L, Vate JFVD. 1997. Greenhouse gas emissions from hydropower, Energy Policy 25(1) (1997): 7-13.

Gagnon, L. 2008. “Civilization and Energy Payback,” Energy Policy 36 (2008), pp. 3317-3320

Geels, FW, **BK Sovacool,** T Schwanen, and S Sorrell. “Sociotechnical transitions for deep decarbonisation,” *Science* 357 (6357) (September 22, 2017), pp. 1242-1244.

George, Alexander and Andrew Bennett. 2005. *Case Studies and Theory Development*. Cambridge, MA: MIT Press.

Gippner, O, S Dhakal, and BK Sovacool. “Microhydro Electrification and Climate Change Adaptation in Nepal: Socioeconomic Lessons from the Rural Energy Development Program (REDP),” Mitigation and Adaptation of Strategies for Global Change 18(4) (April, 2013), pp. 407-427.

Gleick, P. H. 1993. Water and conflict: fresh water resources and international security. *International Security* 18:1, pp. 79-112.

Greacen, Chuenchom, and Greacen, Chris. 2004. Thailand’s Electricity Reforms: Privatization of Benefits and Socialization of Costs and Risks, *Pacific Affairs* vol. 77, no. 3, pp. 517-541.

Green, N., Sovacool, B. K., and Hancock, K. ‘Grand Designs: Assessing the African Energy Security Implications of the Grand Inga Dam,’ *African Studies Review* 58(1) (April, 2015), pp. 133-158.

Haas, Lawrence J. M. 2008. Water for energy: corruption in the hydropower sector, In *Global Corruption Report 2008: Corruption in the Water Sector* (Cambridge: Cambridge University Press, Transparency International, and Water Integrity Network), pp. 85-96.

Hammond, John L. (2011). The Resource Curse and Oil Revenues in Angola and Venezuela. *Science & Society*: Vol. 75, No. 3, pp. 348-378.

Hancock, K and BK Sovacool. “International Political Economy and Renewable Energy: Hydroelectric Power and the Potential for a Resource Curse,” *International Studies Review* (in press, 2018)

Hensel, Paul R., Mitchell, Sara McLaughlin, and Sowers, Thomas E. 2006. Conflict management of riparian disputes. *Political Geography* 25 383-411.

Holdren, John P., and Smith, Kirk R. 2000. Energy, the Environment, and Health, In Tord Kjellstrom, David Streets, and Xiadong Wang (Eds.) *World Energy Assessment: Energy and the Challenge of Sustainability* (New York: United Nations Development Programme), pp. 61-110.

Homer-Dixon, Thomas F. 1994. Environmental Scarcities and Violent Conflict: Evidence from Cases. *International Security*, Vol. 19, No. 1 (Summer), pp. 5-40.

Humphreys, Macartan, Jeffrey D. Sachs, and Joseph E. Stiglitz. 2007. "What is the Problem with Natural Resource Wealth?" In Macartan Humphreys, Jeffrey D. Sachs, and Joseph E. Stiglitz (Eds.) *Escaping the Resource Curse* (New York: Columbia University Press), pp. 1-21.

Hussy, W., Schreier, M., and Echterhoff, G. 2010. *Forschungsmethoden in Psychologie und Sozialwissenschaften*. (Berlin: Springer).

Imhof, Aviva, and Lanza, Guy R. 2010. Greenwashing Hydropower. *World Watch Magazine*, January/February, Volume 23, No. 1, pp. 1-9.

International Energy Agency. 2016. *Key World Energy Statistics 2015* (Paris: OECD, 2016)

International Energy Agency. 2014. *About Energy Poverty*, June 2014, available at http://www.iea.org/topics/energypoverty/.

International Hydroelectric Association, *The Role of Hydropower in Sustainable Development* (Surrey: IHA White Paper, February, 2003).

International Renewable Energy Agency and International Energy Agency. 2017. Perspectives for the energy transition: Investment needs for a low-carbon energy system. Available at http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=3828.

Johnstone, P and P Newell. Sustainability transitions and the state, *Environmental Innovation and Societal Transitions* (in press, 2018).

Kammen, Daniel M. 'Renewable Energy: Taxonomic Overview,' *Encyclopedia of Energy* 5 (2004), pp. 385-412.

Karl, Terry Lynn. 1997. The paradox of plenty: oil booms and petro-states. Berkeley: University of California Press.

Keating, M. (2018) 'IPE and the Global Governance of Hydroelectric Dams', in Goldthau, Keating and Kuzemko (eds.) Handbook on the IPE of Energy & Natural Resources. Edward Elgar

Kibler, KM and DD Tullos. "Cumulative biophysical impact of small and large hydropower development in Nu River, China. *Water Resources Research* 49(6) (June, 2013), pp. 3104-3118.

Koch, Frans H. 2002. Hydropower—the politics of water and energy. *Energy Policy* 30, 1207–1213

Kumar, A., Schei, T., Ahenkorah, A., Caceres Rodriguez, R., Devernay, J.-M., Freitas, M., Hall, D., Killingtveit, A., and Z. Liu. 2011. Hydropower. In *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kuzemko, C.; Keating, F.; Goldthau, A. (2016) The Global Energy Challenge: Environment, Development and Security (Basingstoke: Palgrave).

Kuzemko, C.; Keating, M.; Goldthau, A. (2018) Nexus-thinking in international political economy: What energy and natural resource scholarship can offer international political economy', in Goldthau, Keating, Kuzemko (eds.) Handbook on the IPE of Energy and Natural Resources. Edward Elgar.

Lankester, Tim. 2013. *The Politics and Economics of Britain's Foreign Aid: The Pergau Dam Affair* (London: Routledge).

Lehner, Bernhard, Czisch, Gregor, and Vassolo, Sara. 2005. The impact of global change on the hydropower potential of Europe: a model-based analysis. *Energy Policy* 33, 839–855

Lejeune, A., and Hui, S.L. Hydro Power: A Multi Benefit Solution for Renewable Energy, Reference Module in Earth Systems and Environmental Sciences, Comprehensive Renewable Energy, 2012, Pages 15–47

Lerer, Leonard B., and Scudder, Thayer. 1999. Health impacts of large dams, *Environmental Impact Assessment Review*, Volume 19, Issue 2, Pages 113-123.

Leslie, Jacques. 2014. Large Dams Just Aren't Worth the Cost, *New York Times*, p.5. August 24.

Levent, Aydın. 2010. The Economic and Environmental Impacts of Constructing Hydro Power Plants in Turkey: A Dynamic CGE Analysis (2004-2020) *Natural Resources*, 1, 69-79.

Lundqvist, J. 1998. Avert looming hydrocide. *Ambio*, 27 (6), 428–433

Ma, Jun. 2011. Overexploitation of Hydropower in Southwest China, in *Poverty Reduction and Sustainable Development in Rural China*, Yisheng Zheng (Ed.) (Leiden, Netherlands: Brill), pp. 127-141.

Magee, D. 2006. Powershed politics: hydropower and interprovincial relations under Great Western Development. *The China Quarterly* 185, 23–41

Manyari, Waleska Valença and Osmar Abilio de Carvalho Jr., Environmental considerations in energy planning for the Amazon region: Downstream effects of dams, *Energy Policy*, Volume 35, Issue 12, December 2007, Pages 6526-6534

Matthews, N. 2012. Water grabbing in the Mekong basin – An analysis of the winners and losers of Thailand's hydropower development in Lao PDR. *Water Alternatives* 5(2): 392-411

McCully, Patrick. 2001. *Silenced Rivers: The Ecology and Politics of Large Dams* (London: Zed Books).

McNally, Amy, Magee, Darrin, and Wolf, Aaron T. 2009. Hydropower and sustainability: Resilience and vulnerability in China's powersheds, *Journal of Environmental Management* 90, S286–S293

Merrow, E.W., McDonnell, L., Argüden, R.Y., Corporation, R., 1988.*Understanding the Outcomes of Megaprojects: A Quantitative Analysis of Very Large Civilian Projects*. Rand Corp.

Newell, P. 2018. This volume.

Nugent, D and BK Sovacool. "Assessing the lifecycle greenhouse gas emissions from solar PV and wind energy: A critical meta-survey," *Energy Policy* 64 (February, 2014), pp. 229-244.

OPEC. 2014. *Member Countries*. Available at http://www.opec.org/opec_web/en/about_us/25.htm.

Paish, Oliver. 2002. Small hydro power: technology and current status. *Renewable and Sustainable Energy Reviews*, Volume 6, Issue 6, December, Pages 537–556

Pearse-Smith, Scott William David. 2012. The Impact of Continued Mekong Basin Hydropower Development on Local Livelihoods *Consilience: The Journal of Sustainable Development* Vol. 7, Iss. 1 pp. 73-86

Ping, Chung Tsung, Ng, Sharon, Tan, Geneve, and Neville, Warwi ck. 2008. *Malaysia Inland Waterway Transport in Sarawak* Kuala Lumpur: UNDP Malaysia.

Plummer, Janelle. 2008. Water and corruption: a destructive partnership, In *Global Corruption Report 2008: Corruption in the Water Sector* (Cambridge: Cambridge University Press, Transparency International, and Water Integrity Network), pp. 3-15.

Power, Marcus, Peter Newell, Lucy Baker, Harriet Bulkeley, Joshua Kirshner, Adrian Smith, The political economy of energy transitions in Mozambique and South Africa: The role of the Rising Powers, Energy Research & Social Science, Volume 17, July 2016, Pages 10-19

Raadal HL, Gagnon L, Modahl IS, Hanssen OJ. Life cycle greenhouse gas emissions from the generation of wind and hydro power. *Renewable and Sustainable Energy Reviews* 15 (7) 2011: 3417-3422.

Rafey, W., and Sovacool, B. K. 2011. Competing Discourses of Energy Development: The Implications of the Medupi Coal-Fired Power Plant in South Africa. *Global Environmental Change* 21(3) (August) pp. 1141-1151.

Rew, A., Fisher, E., and Pandey, B. 2000. *Addressing Policy Constraints and Improving Outcomes in Development-Induced Displacement and Resettlement Projects*, University of Wales Swansea.

Robinson, JA, R Torvik, and T Verdier. Political foundations of the resource curse. *Journal of Development Economics* 79 (2006) 447 – 468

Rothfelder, J. 2003.Water rights, conflict, and culture. *Water Resour. Impact* 5(2):19–21

Salazar, J. G. 2000. Damming the child of the ocean: the Three Gorges project. *J. Environ. Dev*. 9,160–174.

Sarkkula, J., Keskinen, M., Koponen, J., Kummu, M., Richey, J. E., and s Varis, O. 2009. *Hydropower in the Mekong Region: What Are the Likely Impacts upon Fisheries?* In F. Molle, T. Foran, & M. Käkönen (Eds.), *Contested waterscapes in the Mekong Region: Hydropower, Livelihoods and Governance* (pp. 227-252). London, England: Earthscan.

Schmitz, H. (2017) ‘Who drives climate relevant policies in the rising powers?’, New Political Economy 22:5, 521-540

Schneider, Howard. 2013. World Bank turns to hydropower to square development with climate change. Washington Post, May 08, 2013.

Scudder, Thayer. 2008. Hydropower corruption and the politics of resettlement, In *Global Corruption Report 2008: Corruption in the Water Sector* (Cambridge: Cambridge University Press, Transparency International, and Water Integrity Network), pp. 96-99.

Simpson, Adam. 2007. The Environment-Energy-Security Nexus: Critical Analysis of an Energy ‘Love Triangle’ in Southeast Asia, *Third World Quarterly* vol. 28, no. 3, pp. 539-554

Singh, S. 2002. *Taming the Waters: The Political Economy of Large Dams in India*. Oxford University Press, New Delhi.

Smith, T. J. 2003. Native American water rights. *Water Resour. Impact* 5(2):16–18

Sohail, M., and Cavill, S. 2007. *Accountability Arrangements to Combat Corruption: Synthesis Report and Case Study Survey Reports*, WEDC (Loughborough: Loughborough University).

Sovacool, B. K. 2008. The Costs of Failure: A Preliminary Assessment of Major Energy Accidents, 1907 to 2007, *Energy Policy* 36(5), pp. 1802-1820.

Sovacool, BK. "Expanding Rural Access to Renewable Energy: Lessons from Sri Lanka's Energy Services Delivery Project (ESDP)," Journal of Resources, Energy, and Development 10 (2) (September, 2013), pp. 79-104.

Sovacool, BK and LC Bulan. "Behind an Ambitious Megaproject in Asia: The History and Implications of the Bakun Hydroelectric Dam in Borneo," *Energy Policy* 39(9) (September, 2011), pp. 4842-4859.

Sovacool, B. K., Nugent, D., and Gilbert, A. 2014a. 'An International Comparative Assessment of Construction Cost Overruns for Electricity Infrastructure,' *Energy Research & Social Science* 3 (September, 2014), pp. 152-160.

Sovacool, B. K., Gilbert, A., and D Nugent, A. 2014b. Risk, Innovation, Electricity Infrastructure and Construction Cost Overruns: Testing Six Hypotheses, *Energy* 74, pp. 906-917.

Sovacool, B. K., Nugent, D., and Gilbert, A. 2014c. Construction Cost Overruns and Electricity Infrastructure: An Unavoidable Risk? *Electricity Journal* 27(4), pp. 112-120.

Sovacool, BK and G Walter. "Major Hydropower States, Sustainable Development, and Energy Security: Insights from a Preliminary Cross-Comparative Assessment," *Energy* 142 (January ,2018), pp. 1074-1082.

Sternberg, R. 2010. Hydropower's future, the environment, and global electricity systems, *Renewable and Sustainable Energy Reviews* 14, 713–723

Swain, A. 2001. Water wars: fact or fiction? *Futures* 33, 769–781.

Terminski, B. 2013. *Development-Induced Displacement and Resettlement: Social Problem and Human Rights Issue*, Research Paper No. 9/2013, Geneva, May.

Themnér, L., and Wallensteen, P. 2014. Armed Conflict, 1946-2013. *Journal of Peace Research* 51(4).

Tilt, B., Braun, Y., and Daming, H. 2009. Social impacts of large dam projects: A comparison of international case studies and implications for best practice, *Journal of Environmental Management* 90, S249–S257

Transparency International. 2008. Executive Summary, In *Global Corruption Report 2008: Corruption in the Water Sector* (Cambridge: Cambridge University Press, Transparency International, and Water Integrity Network), pp. xxiii-xxix.

UCDP/PRIO. 2017. *Armed Conflict Dataset version 17.1, 1946 - 2016*. Available at http://www.ucdp.uu.se/downloads/.

Valença, Waleska, Manyari, Osmar Abilio de Carvalho, Jr. 2007. Environmental considerations in energy planning for the Amazon region: Downstream effects of dams, *Energy Policy*, Volume 35, Issue 12, Pages 6526-6534

Van de Graaf, T and M Bradshaw. The Stranded Wealth of Nations: Oil Exporters, the Shale Revolution and Climate Policy, *RIPE* (this volume).

Vate JFVD. Comparison of energy sources in terms of their full energy chain emission factors of greenhouse gases, *Energy Policy* 25(1) (1997): 1-6.

Wang, Q. G., Du, Y. H., SuY., Chen, K.Q. 2012. Environmental Impact Post-Assessment of Dam and Reservoir Projects: A Review, *Procedia Environmental Sciences*, Volume 13, 1439-1443.

Wang, Pu, James P. Lassoie, Shikui Dong, Stephen J. Morreale, A framework for social impact analysis of large dams: A case study of cascading dams on the Upper-Mekong River, China, *Journal of Environmental Management*, Volume 117, 15 March 2013, Pages 131-140

White, Franklin. 2002. Water: life force or instrument of war? *The Lancet* 360 (December), S29-S30.

Wolf, Aaron T., Kramer, Annika, Carius, Alexander, and Dabelko Geoffrey D. 2005. Managing Water Conflict and Cooperation, *State of the World 2005* (Washington, DC: Worldwatch Institute), pp. 80-99.

Wolf, Aaron T. 2007. Shared Waters: Conflict and Cooperation, Annual Review of Environment and Resources, Vol. 32: 241-26

World Bank. 2013. *Six Questions on the Cost of Corruption*. Available at http://go.worldbank.org/KQH743GKF1

World Bank 2017a. *Data*. Available at http://data.worldbank.org/.

World Bank 2017b. *Worldwide Governance Indicators*. Available at http://info.worldbank.org/governance/wgi/index.aspx#home.

World Commission on Dams. 2000. *Dams and Development: A New Framework for Decision-Making* (London: Earthscan).

Yang, Ming. 2003. China's rural electrification and poverty reduction, *Energy Policy* 31, 283–295.

Zeitoun, Mark, and Warner, Jeroen. 2006. Hydro-hegemony – a framework for analysis of trans-boundary water conflicts, *Water Policy* 8 435–460.

Zhao, Xingang, Liu Lu, Liu Xiaomeng, Wang Jieyu, Liu Pingkuo, A critical-analysis on the development of China hydropower, *Renewable Energy* 44 (2012) 1-6